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Optimizing the Electronic Health Record for Cardiac Care

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Final Progress Report

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Structured Abstract (Maximum of 250 words to include the following elements)

- Purpose: The Electronic Health Record (EHR) is now recognized as a significant contributor to clinician burn-out. We undertook a multi-center, multi-vendor study to understand clinician's needs and wants, and to develop and test a prototype EHR based on clinician-centered design.

- Scope: Cardiovascular clinicians and patients practicing at 4 academic and 4 private healthcare systems.

- Methods: Convergent parallel mixed methods using a simulated patients to provide consistency across the sites and avoid privacy and security concerns. Establish baseline views from 66 clinicians at 8 sites. Analyze the data and build a functional prototype using agile techniques, validated with external experts, finally, retest clinicians in head-to-head measures between prototype and installed EHR using the system usability scale (SUS).

- Results: Baseline results: Across 8 sites and 6 different installed EHRs SUS averaged 47.1 (less than 68 indicates poor usability, 85 excellent usability). Clinicians complained about unnecessary clicks and documentation of impertinent negatives. What they desired was an EHR that supported continuity over episodic care, active involvement of patients in data collection, appropriate data pushed to them, fulfilling billing requirements without bloating the note, and support for structured data and patient narrative. Follow-up testing of our prototype versus installed EHR with 25 clinicians across our test sites demonstrated a significant improvement in SUS scores (78.1 versus 48.2, $p<.0001$).

- In conclusion, clinician-centered design can result in substantial improvements in EHR usability independent of academic versus private practice. This prototype can inform EHR vendors of desired functionality

- Key Words
    - Electronic Health Record
    - Usability
    - User-Centered Design

Purpose (Objective of Study)

The current electronic health record evolved as a product of traditional paper-based records and the need to provide documentation to support billing. Adoption was then mandated and now has a penetration of 96% of practices. However, the expansion occurred with minimal involvement of clinicians (for our study clinicians are defined as nurses, advanced practice providers (APPs), and physicians). Our studies prior to 2014 indicated that clinicians believed that, as designed, the EHR had a negative impact on patient care. Those concerns have been borne out. It is now widely accepted that clinicians spend twice as much time with their computer than their patients and that the EHR is a major source of clinician burn-out.

The purpose of this study is to demonstrate that problems encountered in using the EHR can be overcome by using the principles of user-centered design and validated by building and testing a prototype EHR that addresses clinician's needs and potentially reduce clinician burn-out.

Scope

- Background

The electronic health record (EHR) was expected to transform the delivery of health care services in the United States; reducing costs and improving health outcomes through standardizing practice and reducing medical errors. The reality, however, is that EHR adoption has not consistently lowered healthcare costs or improved patient care. Some of the failures of EHR adoption have been placed on the physician's resistance to adopt new technology. Our previous work and the work of others suggested that physician resistance to adoption of the EHR, even among tech-savvy super-users, was based on the perceived negative impact on clinician workflow, communication, and insufficient functionality to assure safe management their patients.

There is growing support for the need for a fresh look at making the EHR more functional for clinicians, including the importance of domain knowledge and roles, and access to evidence-based and technology-enabled data at the point of care. The inability of many EHRs to fulfill these goals has stimulated investigation by the American Medical Informatics Association's Task Force on Usability, which recommended human factors research to improve EHR usability. Attention to usability for EHR system designs that support the cognitive work of clinical users is also recognized as a requirement by the Healthcare Information and Management Systems Society. Usability is defined by the International Standards Organization (ISO) as the "effectiveness, efficiency and satisfaction with which specific users can achieve a specific set of tasks in a particular environment".

In this research grant we chose to use the ISO definition of usability instead of the Zhang and Walji usability model of usable, useful and satisfying. An excellent comparison is presented in Linda Harrington's recently published book on usability; the ISO definition is a better fit for our conceptual framework. Specifically we believe that embedding patient safety as a subset "usable" constrains the comprehensive evaluation of patient safety. Patient safety extends not only beyond usable but also beyond EHR usability. In our model, improved patient care and patient safety sits alongside improved workflow and improved information flow as desired outcomes of EHR optimization. The impact of the EHR may not always be predictable; for instance, improving efficiency can reduce cognitive overload (good for the patient safety) but improving efficiency could also lead to short cuts that eliminate necessary safety checks (bad for the patient safety). Similarly, adding automated alerts that require actions may identify potential harm to the patient or may lead to fatigue or even dangerous care. An example of a dangerous alert was noted at our institution. A drug-disease interaction (epinephrine and chest pain) was generated. The recommendation and the only action suggested by the best practice alert was to discontinue the epinephrine prescription. Because the chest pain was not cardiac and the epinephrine was used to treat anaphylaxis one simple click would have endangered the patient's life. Thus, by layering patient safety as dependent variable (along with workflow and information flow) as a measured component of usability will allow us to explore patient safety in a more holistic manner.

While the benefits of a usability-based approach to EHR requirements are well documented, the practical application of usability assessment into EHR software design and development is limited. Recommendations by industry and government experts point to an insufficient focus on usability as an ongoing problem.

- Context

Our research focused on cardiovascular clinical scenarios. Cardiovascular disease is the leading cause of death in the US, with nearly 600,000 deaths per year. Death rates for cardiovascular disease have declined substantially since 1999, 44% due to lifestyle and environmental changes, and 47% due to increased use of evidence-based medical therapy. Yet nearly 40% of US citizens are projected to have some form of cardiovascular disease by 2030, and estimated costs for treatment are projected to grow to nearly $1.5 trillion. The management of cardiovascular disease; is by its nature, multi-dimensional (acute and chronic, inpatient and outpatient, primary and secondary prevention) and multidisciplinary (cardiologists, primary care providers, emergency room physicians, CCU nurses, catheterization lab nurses and technicians, and outpatient nurses and technicians), and thus it is ideal to test the full functionality of the EHR. Finally our access to cardiovascular content experts through our association with the American College of Cardiology (ACC) and, in particular the ACC Informatics and Health Information Taskforce (IHITTF) is a unique strength.

- Settings

Four academic and four private practice settings were included. The academic settings included the University of Nebraska Medical Center, Indiana University, Duke University and the Veterans Administration Medical Center in Omaha, affiliated with Creighton University. The four private settings were Swedish Medical Center in Seattle Washington, St. Vincent Health System in Indianapolis, Indiana, Parkview Health in Fort Wayne, Indiana, and Faith Regional Health in Norfolk, Nebraska. Simulations of the clinical encounters were performed in clinic rooms or meeting rooms adjacent to clinical rooms. This included evaluation of outpatient visits, emergency room evaluations, and cardiac catheterization labs.

Early in the process of listening to clinicians' wants and needs we identified that a potential major step forward would be to more actively involve the patient in their health and health record. Therefore we added patients into our model of the healthcare team and created a personal health record prototype. The prototyping of desired personal health record (PHR) functionality was performed only at the University of Nebraska Medical Center's clinical partner Nebraska Medicine.

- Participants:
  - 81 clinicians were recruited from the eight clinical sites mentioned above. A minimum of 5 clinicians from each site were recruited. This was a convenience sample based on clinician availability but reflected the demographics of that site.
  - 105 patients were recruited for the design and development of the personal health record. Patients were recruited at the time of their regular clinic visit and recruited to represent a broad demographics with an intentional over-representation of at risk populations.

- Incidence: N/A

- Prevalence: N/A

Methods

- Study Design

1) Understanding the wants and needs of clinicians and patients:

The research design consists of two steps – an online EHR usability survey, followed by a clinical simulation using the cognitive walkthrough. In the first step, research participants, representing the health care team (physicians, fellows and nurse practitioners as well as nurses and primary care providers) will be identified. Participants will be issued an invitation to complete a brief online system usability survey to provide an overall evaluation of their experience with computers in general and their current EHR user in particular. This will serve as a benchmark. Our survey is based on the System Usability Survey (SUS), a commonly used evaluation tool, with ten questions with Likert-scale responses. The survey will provide data about the provider's ability to navigate the menu, the ease of finding information, as well as how satisfied they are with the system.

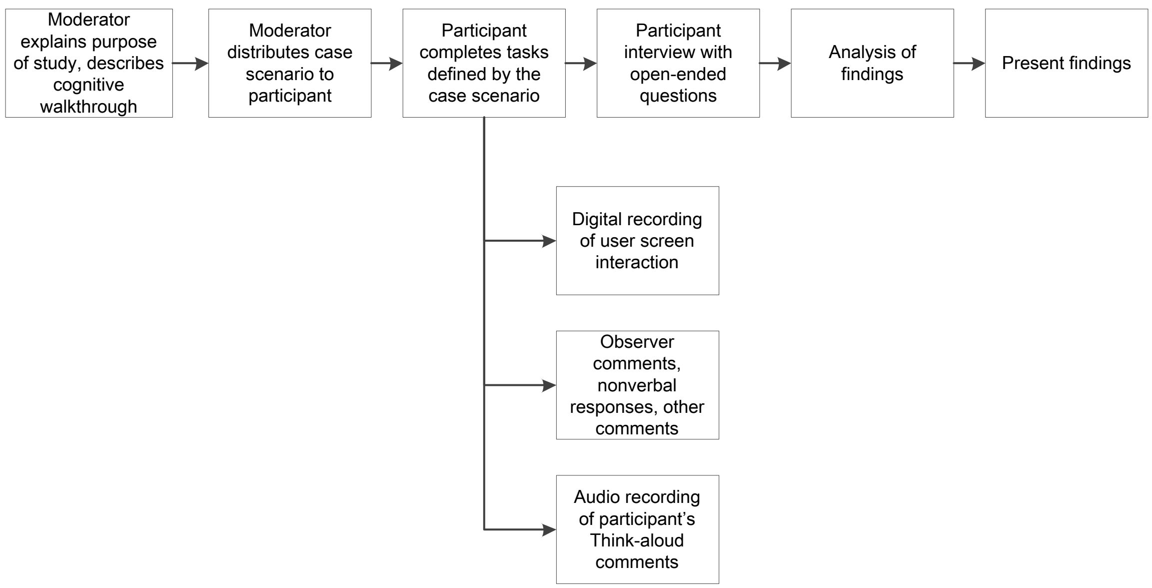
Survey responses will be loaded into Excel. Participant's scores will be summarized, multiplied by 2.5 to convert the original scores of 0-40 to a standardized score of 0-100. Using Brooke's analysis strategy, respondents who score above 68 will be classified as satisfied users. Respondents who score below 68 will be classified as dissatisfied users. If the number of respondents in either category is not significant, additional participants will be identified, and invited to complete the survey.

In the second step, a diverse group of research subjects will be recruited based on their demographics and qualitative scores. For instance, by inviting both satisfied and dissatisfied users, we will be able to record how they approach information retrieval, documentation and communication and determine if different use patterns exist. The session will be conducted in a realistic clinical setting using the clinical scenarios and trained simulated patients. The test environment will be prepared using the portable usability lab that connects the subject's workstation to capture audio and screen data.

The moderator will introduce the subject to the system, present an overview of the session, and describe the think aloud protocol. The subject will be introduced to the trained simulated patient, and receive a written copy of the clinical scenario. The investigators will digitally record the sessions, observing user's system interactions as they complete the tasks defined within the scenario, and complete field notes which will include observations, participants' comments while using the system, where and when system problems occur, along with nonverbal user feedback. A second, independent observer will be present to ensure digital recording of video and audio, record comments and non-verbal responses and track completion times.

A post-walkthrough interview will follow, where participants will answer open-ended questions and discuss perceptions of usability and satisfaction. After the user session, task measurements specified by the case scenario will be recorded, user screen manipulations and audio files will be stored, and field notes will be completed.

Data will be collected and analyzed in an iterative manner. Quantitative data will include successful task completions as a measure of effectiveness, time to complete tasks and associated number of mouse clicks as measures of efficiency; and task difficulty and task satisfaction ratings as measures of satisfaction. Results will be examined using descriptive statistics to measure central tendency and variability.



Cognitive Walkthrough: This figure demonstrates stepwise approach to the cognitive walk-through.

Qualitative data including the digital recordings and field notes will be reviewed by the investigators. All documents will be imported into NVivo 8.0, and identified by session date and time. The investigators will independently review each session's recording to identify patterns within the participants' responses, annotating the recording with relevant concepts through NVivo. Using the method of grounded theory and constant comparison, the investigators will meet in a series of three or more review sessions to compare concepts, resolve discrepancies in interpretation, explore the various meanings of words, discuss emergent themes, and resolve ambiguities, until consensus is achieved and potential biases in interpretation are reconciled. Important user themes will be built using this iterative process of reviewing and grouping concepts during the review sessions. The relevance and importance of themes will be assessed by the investigators using a rating schema of frequency, convergence and intensity. Frequency represents the number of times that the topic appears in the users' discussion, and is documented using NVivo's frequency reporting feature. Convergence, the relative occurrence of the topic across the groups of satisfied and dissatisfied users, is assessed by each investigator as high, medium, or low. Intensity is defined as the emotion and importance of the topic to the user, using a scale of high, medium or low based on a subjective analysis of the digital recording for vocal tone, pace and volume. According to grounded theory, we will continue an iterative process of review and data collection until no new concepts are discovered and content saturation is reached. A summary of relevant themes will be compiled.

Resulting themes from the quantitative and qualitative analyses will be reviewed. Using the CPMM framework, results from the two approaches will be merged to identify and resolve differences between the sets of results, and to clarify findings through triangulation, providing a more comprehensive interpretation of EHR usability requirements for the cardiac care team, and a broader understanding of the implications of EHR design.

2) Agile Development of Desired Functionality

In parallel with understanding the wants and needs of clinicians we will conducted a heuristic evaluation of the current EHR to assess usability using the clinical scenarios. Heuristic evaluation is a commonly used expert method where Human-Computer Interaction (HCI) specialists study the interface in depth and look for properties that they know, from experience, will lead them to identify potential problems. The University of Nebraska Research team - consisting of HCI experts from the UNO College of Information Science and Technology and UNMC will perform a robust heuristic evaluation process. ACC domain experts will also participate in the evaluation based on Nielsen's 10 heuristics, plus an additional 3 identified by Deniese Pierotti, Xerox Corporation. The list includes criteria to evaluate productivity and efficiency, error prevention, user control, ease of learning, flexibility of use, and user satisfaction. The expert team will meet in group sessions (in person and via webinar) to review the meaning of each heuristic and discuss its relevance to EHR user interface design and then assess how well the EHR adheres to the heuristic on a scale of 1 to 5. Also, comments will be captured on how the EHR could be modified. Heuristics that are not followed will be prioritized according to Impact – number of users it affects, severity, the consequence if the heuristic is not followed (patient safety in particular), and the frequency – how often a user would encounter the event where the heuristic was not followed. The results of the heuristic evaluation will provide us with a prioritized list of actions that need to be taken to improve the user interface. In essence we will have a robust action plan for enhancements and features in the prototype. We discuss the prototype development process next.

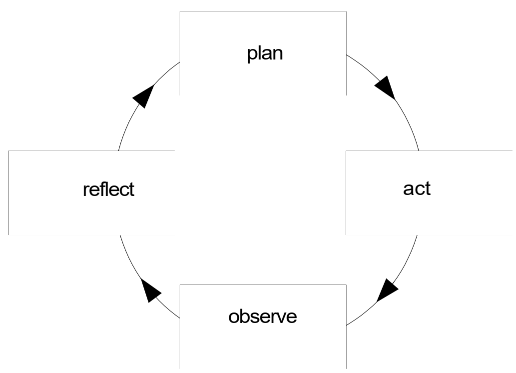
In the assessment, each evaluator enters a rating on how well the current-state EHR enforces the heuristic. During this process we will capture comments from each evaluator indicating where the current-state EHR violates the heuristic and where it can be improved. Examples of success or failure will be discussed and the team will decide which heuristics are applicable. Each evaluator will enter his or her rating independently and also add comments to explain the rating, especially if the system did not comply with the heuristic. The current-state EHR will be projected for all to view during these discussion sessions. After all the ratings are completed, we will analyze for inconsistencies in our evaluations (standard deviations) and then prioritize the results based on the ratings. We will also capture other enhancement ideas that are generated from our analysis and discussion. We will create a report on the general and specific findings to be included in the design requirements for an optimized EHR prototype.

3) Electronic and Personal Health Record Prototyping

The grant originally was going to develop wireframe prototypes to test desired functionality. Initial testing indicated that wireframes, even complex wireframes did not create the veracity necessary for clinicians to concentrate on the clinical encounter. Therefore, we built a fully functioning web-enabled prototype using Microsoft SQL to support the database needs of the prototype, thus supporting documents, lab values and images. The front end used Bootstrap (Bootstrap.com) and Angular (Angular.IO)

In developing these models, we employed two highly respected information system development methodologies: Value-Based Software Engineering principles and Agile Development methods. In addition, we followed the Action Research methodology approach as we prepare for each iteration. Action research has the dual intention of improving practice and contributing to theory and knowledge (Argyris et al. 1982; Checkland 1981).

In our project we will employed all four activities of action research: Plan, Act, Observe, and Reflect. 'Plan' concerns exploration of the research environment and the preparation of the intervention (create the wireframe model). 'Act' refers to the actual intervention made by the investigator (Intervention is the implementation the new design changes to wireframe model and thee user evaluation of the new design). 'Observe' concerns the collection of data during and after the actual intervention to enable evaluation (collect data from the users' feedback). Finally, the 'Reflect' activity analyses the collected data and infers conclusions (Analyze the feedback from the user and identify the next intervention – user interface design changes) that may feed into the 'Plan' activity of a new iteration.



This is a schematic of the Action Research process. This approach will allow us to quickly design and build what the end-users (the cardiac care team) want and convert those results into a set of requirements that will directly impact the workflow, information flow and decision support needs of the cardiac care team. By partnering with the ACC we will be able to work with the EHR's success-critical stakeholders (SCS) eliciting their value propositions with respect to the system; and reconciling these value propositions into a mutually satisfactory user interface.

Value Based Software Engineering Philosophy

Value Based Software Engineering (VBSE) theory states stakeholders beyond users are critical to the success of the software development project and must be considered. VBSE asserts that traditional software engineering practice and research is value-neutral where each deliverable is given equal importance across the board i.e. no prioritization is done and no cut-offs are set when unit costs exceed derived unit benefit. VBSE represents a paradigm shift from value-neutral to value-based thinking.

Value Based Software Engineering principles are explicitly concerned with stakeholders' value concerns in the application of science and mathematics by which the properties of computer software are made useful to people [65]. In other words, what do critical-success stakeholders value as important requirements of an information system, and how these competing requirements can be integrated to create a WIN-WIN scenario for all stakeholders. The objective of Value Based Software Engineering principles are to integrate value considerations into the full range of existing and emerging software engineering principles and practices, and develop an overall framework in which they compatibly reinforce each other.

At the core of Value Based Software Engineering is Theory W. Theory W is defined as determining what is important to each of the success-critical stakeholders (SCS) and defining how success is assured for all SCSs. The desired end state for requirements then is a negotiated win-win state in which the system stakeholders agree to an option from which all can derive benefit. We operated in a value-based setting rather than a value-neutral setting. A value-neutral setting is where every objective, requirement use-case defect are treated equally important. In the past, this approach has been acceptable; however, today there are many competing values. Different stakeholders have different value propositions. In order to optimize the EHR as many as possible value propositions need to be addressed.

4) Testing the Prototype EHR

A new simulated complex patient was developed for the final testing of the prototype versus the installed EHR. Twenty five clinicians were recruited from the eight clinical sites. The clinician recorded SUS scores for their installed EHR. Orientation to the prototype EHR was then performed prior to formal testing with the simulated patients. This orientation took between 15 and 25 minutes. The simulated patient had recently been discharged from the hospital and was establishing care as a new patient with the clinician. This allowed us to fully test the review, interview, and document process. Debriefing and SUS scores were collected after the simulation.

5) Evaluation and Testing of the Prototype PHR

The methods described above (1-4) were used with patients to create a functional PHR prototype with some modifications. Initially we tried using simulation with patients but quickly discovered that was too complex and let them use their own situation and problems. The use of the EHR is a mandate not a choice, not so with patients. We, therefore, looked into barriers of adoption from a socio-technical framework. Near the end of the grant we received funding to add eye-tracking. We then added measures of cognitive load through the NASA taskload index and eye tracking.

- Data Sources/Collection: See above

- Interventions: Development and testing of the prototype personal health and electronic health record

- Measures: Convergent parallel mixed methods (quantitative and qualitative data collection and analysis of clinicians and patients, and expert consensus building).

- Limitations:

- We initially were concerned that clinicians would not accept a simulated patient as realistic. Debriefing, observation, and post-simulation surveys allayed that concern.

- Early in our discussions with clinicians in became apparent that we needed to bring patients “on to the health care team”. This recognition was transformative. Building data collection into the PHR and aligning patients with clinician workflow produced substantial gains in perceived efficiency and effectiveness.

- A challenge to this project was the evolution of the installed EHR as the project progressed. We therefore, modified the project to allow a contemporary comparison of the clinician’s installed EHR compared to the prototype.

- We were able to add cognitive load testing through the NASA task index and eye tracking to our PHR evaluation but not the EHR prototype. Understanding and evaluating clinician cognitive load would add insight into the issues related to clinician burden.

- While we have demonstrated significant improvements in clinician satisfaction, we observed but did not quantitative measure improvements in efficiency and effectiveness. That testing is out of scope for this project.

- Ultimately, we produced a prototype in a simulated clinical environment. We validated the concept. The next step is to build these learnings into the live clinical environment.

Results

- Principal Findings

1-Understanding the issues and needs of clinicians:

Stimulated by the American Recovery and Reinvestment Act of 2009, EHR systems have been installed in 96% of hospitals across the US. However, system usability scores have remained poor (Table 1) with concerns being similar to our initial studies of EHR adoption presented in 2007 (7). Key findings include the perception that the EHR impedes clinician workflow, inhibits communication, and adversely affects decision-making, ultimately concluding that the EHR interfered with patient care. There was great concern that reviewing patient records and documenting the patient encounter was burdensome, especially the documentation of “impertinent negatives”. It was a common comment that the EHR added 90 minutes to the workday. Copying and pasting was frequently mentioned as a method to efficiently bring forward information from previous encounters. Most did not use the problem list because it became “bloated” and hard to manage. While this study was specifically not designed to compare one EHR versus another, we could not readily detect that one system performed substantially better than any other.

2- Identification and prioritization of EHR framework clinical tasks and related component concepts:

It became clear from our initial interviews that the ability to improve usability (efficiency, effectiveness, and satisfaction) could not be accomplished simply by reducing clicks; therefore, we evaluated all of the tasks necessary to complete a clinical encounter then deconstructed the encounter into the essential components. Again leveraging the ThinkTank system, we independently validated assumptions and designs of the research team via survey of the American College of Cardiology Informatics and Health Information Technology Taskforce.

The key findings included the following;
-A clinical encounter is deconstructed into three steps: review, interview, and document, and that process in iterative.
-Moving from primarily analog text to semi-structured data-based documentation is essential.
-Care needs to move from encounter-based to a continuum.
-Data can be entered by the patient or the clinician but must be verified by the treating physician or APP.
-Clinical problems (symptoms, diagnoses, or therapeutics) can efficiently drive dataflow and workflow.
-Domain knowledge and clinical expertise drive the information/data needs of the clinicians.
-Based on Delphi modeling the data needed for computational purposes is typically constrained and independent of clinical location or installed EHR.
-Clinicians want appropriate data pushed to them, including clinical images. What clinicians want pushed can be managed by their domain expertise and the clinical problem being addressed, thereby reducing time needed to review information and create a mental model of the patient's conditions.
-Understanding that data has persistence beyond the encounter, i.e., moving from encounter-based to a continuous care model. Thus, data relevant to a patient with, say a heart transplant should persist beyond the individual encounter.
-A well curated problem list is important to improve efficiency and effectiveness.
-Robust structured data plus a concise clinical narrative can accurately and efficiently convey the patient's problems.
-Of note, in 60 simulations no clinician requested or used on-line educational material during the clinical encounter.

3-Prototype Construction and Validation:

Development of the EHR prototype reflected integration of the key findings elucidated via the qualitative work (clinical tasks, data flow, workflow, distribution of healthcare documentation across the members of the healthcare team, active inclusion of the patient, etc.). The prototype required two high resolution monitor screens to achieve the desired efficiency, effectiveness and satisfaction targets. Reviewing and validating data was predominately a function of the left monitor screen. By keeping key data and narrative persistent on the left screen, information synthesis was facilitated. We created a library metaphor to house information relevant to billing and collections that was otherwise of little use in clinician and patient communication to reduce "note bloat". Persistence of key data, the ability to review the raw data/images and ability to easily validate patient and nursing entered data was viewed by clinicians as major efficiency gains. Although concerns about the utility and curation of the problem list were voiced, clinicians understood and appreciated having the EHR compile and aggregate data while anticipating diagnostic testing and therapeutic intervention recommendations.

	Installed EHR SUS (Initial)	Installed EHR SUS (final)	Prototype EHR SUS (final)
SUS Score	46.7 +/- 16.6	48.1 +/- 16.7	77.8 +/- 12.4
Satisfaction Score	3.10 +/- 0.93	3.16 +/- 0.85	4.40 +/- 0.58

Table 1 presents the System Usability Surveys at the time of initial testing (n=35) and final testing (n=25) of the installed EHR, and the prototype EHR. There was no statistically significant improvement in SUS or Satisfaction scores (1-5, from strong disagree to strongly agree) between initial and final installed EHR, p=NS. There is a highly significant increased level of SUS scoring and satisfaction with the prototype EHR, p<0.001

4-PHR Evaluation and Prototyping:

- Impact of Age on Desired PHR functionality.

  We evaluated the impact of three age ranges on desired PHR functionality, less than 40, 40-64, and 65 and older. Younger patients had no fear of technology, they in fact, preferred electronic documents to paper and mobile devices. The older patients gave mixed results, there was substantially greater fear of technology including security and privacy, preference of monitor to mobile devices.

- Impact of Demographics and Social Determinants of Health on PHR adoption.

  We next sought to study the adoption of the PHR based on the demographic and social determinants of health. In this study using group of patients with diverse demographics (race and ethnicity, urban, suburban and rural based on zip codes) and using measurements of health literacy, medication adherence measures, patient activation and computer self-efficacy, only computer self-efficacy was significant. All other demographic and social measures were not significant. While this study was relatively small (75 patients) it suggests that individual measures (personalization) rather than demographic grouping maybe be necessary to demonstrate improvements in care.

- The PHR Prototype and Cognitive Load

  To potentially move the needle on patients limitations due to computer self-efficacy we introduced eye-tracking and the NASA task index to measure cognitive load. Cognitive load has three components: intrinsic, extrinsic and germane cognitive load. Better design affects extrinsic cognitive load. By altering our design we have been able to minimize extrinsic cognitive load.

- **Outcomes:** Measuring outcomes was out of scope of this grant.

- **Discussion:**

  This project had three goals: to understand clinician issues and needs in terms of EHR functionality, to refine and validate these expectations into a framework that supports clinician defined functionality, and to demonstrate a system with improved usability that reduces clinician burden. As demonstrated between baseline and final EHR testing, system usability scores remain poor despite familiarity with the installed EHR, (SUS scores below 68 are considered poorly designed) Despite a very short training period , our prototype EHR overcame the barriers of currently installed EHRs with scores that indicate high satisfaction with the EHR. The major enhancements include: bringing the patient actively into the data collection process, the pushing of domain specific content (including images) with a concomitant reduction in the need to search for relevant content,, creation of a bookshelf for data that was reviewed but is not needed for information synthesis or communication (i.e., separating billing requirements from clinical documentation), and bringing quality documentation into the workflow.

- **Conclusions:**

  Clinical care is practiced the same across the country and is independent of installed EHR, therefore best practices in EHR implementation can be established. Clinicians want good data pushed to them, and easy access to good patient narratives. They want intuitive support for documentation and ordering. They also want to eliminate "impertinent negatives" and note bloat. User-centered design can be a powerful tool to reduce clinician burn-out without sacrificing quality and patient safety.

- **Significance:**

  More work needs to be done to confirm and validate these findings. However, this results of this project hold the promise of making clinicians more efficient, effective and satisfied with their EHR. There are 1,000,000,000 ambulatory clinic visits annually. Trimming even 2-3 minutes per encounter would produce substantial cost savings without sacrificing quality.

- **Implications:**

  AHRQ and the Office of the National Coordinator for Health Information Technology should support more research and development of non-incremental solutions to reduce clinician burden.

List of Publications and Products

Journal Articles

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Pachunka, E., Windle, J., Schuetzler, R., Fruhling, A., (2019). Natural-Setting PHR Usability Evaluation using the NASA TLX to Measure Cognitive Load of Patients. Proceedings of 52nd Hawaii International Conference for System Sciences, Grand Wailea, Maui, January 8-11, 2019.

Presentations

Clarke, MA (2019 Apr) 4th Annual Midwest Bioinformatics "Increasing the Use of Personal Health Records through User-Centered Design"

Clarke MA (2019 Mar) University of Missouri Colwill Seminar: "Optimizing the Personal Health Record for Cardiac Patients."

Windle, TA. (2018, September 24). Improving Healthcare Data Interoperability. PEW/DCRI, Stakeholders Meeting, Duke University, Durham, NC (Remote).

Windle, TA. (2018, July 12). Interoperability Usability for Specialty Registries. PEW/DCRI, Stakeholders Meeting, Duke University, Durham, NC (Remote).

Windle, TA. (2018, January 8). Personal Health Record Usability. American College of Cardiology Informatics Committee, Cardiology Specialty Steering Board, Epic Campus, Verona, WI.

Windle, TA. (2017, July 15). EHR Usability Demonstration. Beyond Boundaries: ONC's 2017 Technical Interoperability Conference, Washington Plaza Hotel, Washington, DC.

Tcheng JE. (2019, March 22) Envisioning Data Liquidity: The DCRI-Pew Data Interoperability Project. NIH Collaboration Grand Rounds

Windle, JR. (2019, September 13) Deconstructing the Clinical Encounters. Cardiovascular Medicine Grand Rounds, UNMC

Windle, JR. (2019, October 23) Human and Computer Collaboration in Medicine. Great Plains IDeA Clinical Translation Research Meeting